VALTION MAATALOUSKOETOIMINNAN JULKAISUJA N:o 159
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ON THE THERMAL CONDITIONS IN MINERAL AND PEAT SOIL AT PELSONSUO IN 1955–1956

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PELSONSUO

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KIVENNÄISMAAN JA TURVEMAAN LÄMPÖOLOISTA PELSONSUOLLA VUOSINA 1955—1956

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Introduction

The soil types are classified according to two groups, mineral soils and peat soils, this classification being based on the fact that the former are composed of mineral substances and the latter of organogenic matter. The primary reason why these two soil type groups show very great differences as a substratum for plants and why their cultivation requires somewhat different measures of fundamental amelioration and cultivating procedure, is their difference with regard to chemical and physical properties.

Numerous investigations have clarified the manner in which the mineral and peat soils differ from each other with respect to their thermal conditions, as well as the causes for these differences (Homen 1896, Karsten 1911, Bouyoucos 1913, Keen and Russel 1921, Smith and Byers 1938, Semb 1939, White 1946, Kersten 1949, Gloune 1950). Briefly, the reasons are:

- The thermal conductivity of mineral soil is higher than that of peat soil.
- The specific heat of mineral soil is higher than that of peat soil in the case of dry soil, but lower in the case of wet soil.
- Less thermal energy is bound by means of evaporation from mineral soil than from peat soil.
- Mineral soil absorbs less radiant energy than peat soil.
- The freezing of the soil takes place in a different manner in mineral soil and in peat soil, which affects the thermal conditions.

Although the causes responsible for the differences in thermal conditions between mineral and peat soils are fairly well known, less information is available as to the temperature differences which occur under various circumstances. To the author's knowledge, prolonged investigations in Finland have been carried out only by Homen (1896) at Mustiala. Owing to the fact that a continuous snow cover and freezing of the ground occur fairly regularly in the wintertime in our country, it is difficult under Finnish conditions to apply any of the results of investigations performed in countries where snow cover and frozen ground are absent.

Since in the conditions in our country the rate of development of cultivated plants is of great importance, e. g., in view of the occurrence of night frost, an attempt has been made in the investigations of the Frost Research

Station to pay attention to such factors which may affect this variable. One particular group of these investigations thus consists of various studies relating to the thermal conditions in the soil. — In the following, a review will be given of the temperature measurements performed in mineral and peat soils.

As has been said before, there are numerous earlier investigations which concern the causes of differences in temperature between mineral and peat soil. Therefore it has not been considered necessary to deal very thoroughly with this aspect of the topic. The main purpose of the investigation was rather that of obtaining a satisfactory picture of the thermal conditions in two soils belonging to the mentioned soil type groups, primarily with a view to their consideration from the standpoint of plant cultivation.

I. Site of investigation and meteorological conditions

1. Site of investigation

The investigations were carried out at Pelsonsuo ($\lambda = 26.5°$ E, $\varphi = 64.3°$ N) in the years 1955—1956. The test area was part of a bog area of 14 000 ha, where the base soil came up to the soil surface at one point. The points of temperature measurement on the mineral and peat soils were situated on level soil at a distance of about 2 km from each other.

Towards the west, south and east of the test points the nearest edge of the forest was several hundred metres distant. Towards the north the distance to the edge of the forest from the temperature measurement point on the peat soil was 100 m, and from the temperature measurement point on the mineral soil it was 200 m (Fig. 1).

The points of measurement were located in cultivated fields with open ditches of 90 cm depth and a strip 20 m wide between each two ditches (centre of ditch to centre of ditch). The thermocouples were inserted at a distance of 4 m from the edge of the ditch. The measuring points were kept free of vegetation.

At the point of measurement on the peat soil the peat layer had a thickness of 156 cm. Between the depths of 0 to 100 cm the peat was poorly humified sedge peat, and between 100 and 156 cm it was moderately well humified Bryales peat. The base soil was coarse sand, the 0.6—0.2 mm fraction containing 1 %, the 0.2—0.006 mm fraction 95 %, the 0.06—0.02 mm fraction 3 % and the 0.02—0.006 mm fraction 1 %.

At the point of measurement on the mineral soil the dominant soil type was coarse sand. The results of its mechanical soil analysis are seen from Table 1.

The peat soil had been cleared for cultivation in 1952, the depth of the ploughing done at that time being about 30 cm. At the subsequent levelling of the area no ploughing was done. The thermocouples were inserted on 8. IX. 1952.

The point of measurement on the mineral soil grew grass prior to the commencement of the measurements. The surface, to a depth of about 3 cm, was removed from the point of measurement on an area of 16 m^2. The thermocouples were inserted on 30. V. 1955.

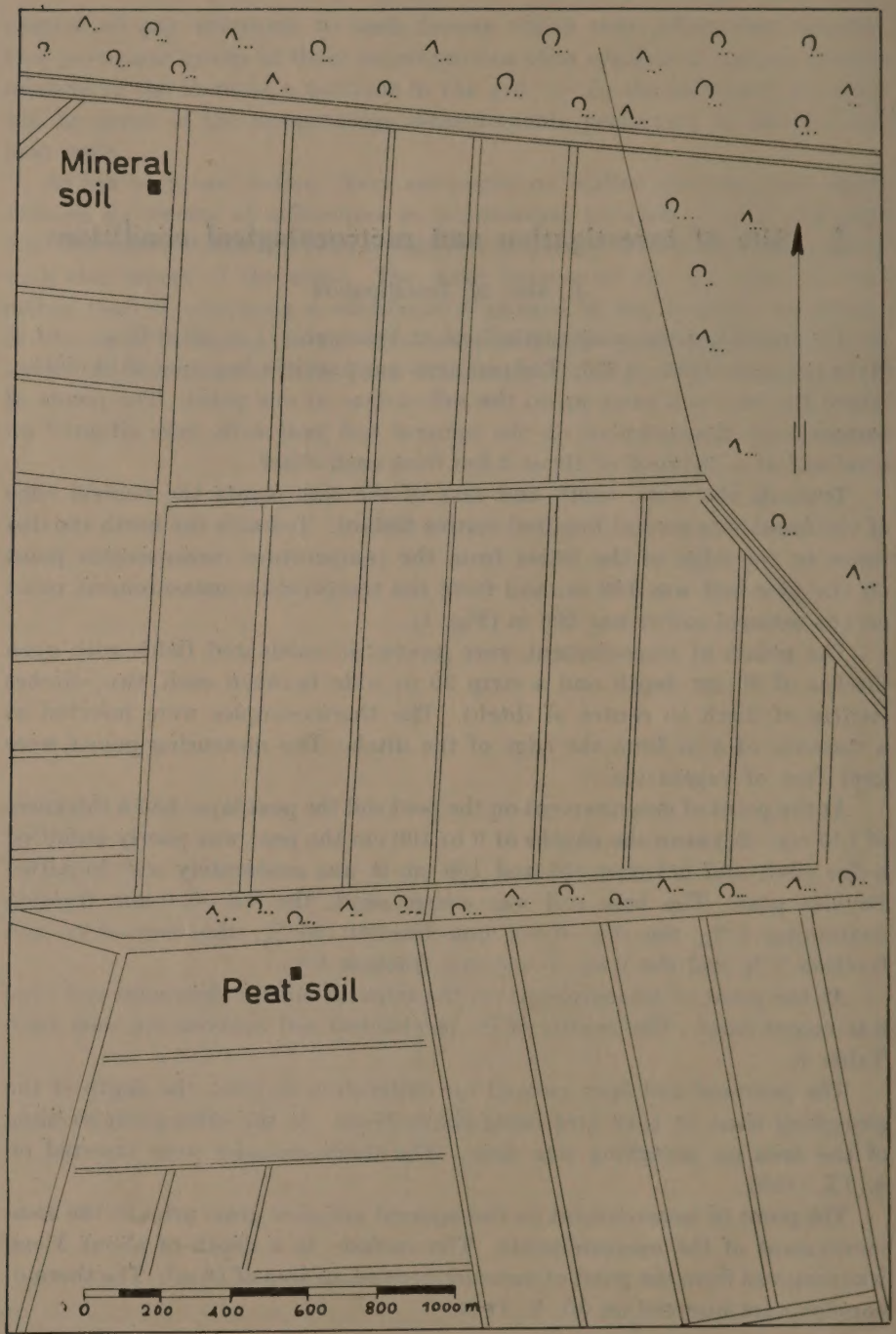

Fig. 1. Map showing location of the temperature measurement points in the mineral and peat soils.
Kuva 1. Lämpötilan mittauspaikkoja osoittava kartta.

Table 1. Composition of the mineral soil at the point of temperature measurement.

Taul. 1. Maan kokoomus kivennäismaan lämpötilan mittauspaikalla.

Soil layer *Maakerros* cm	Grain composition, % *Raekokoomus %*				
	Gravel *Sr* 2.0 mm	Very coarse sand *KHk* 2.0—0.6	Coarse sand *HHk* 0.6—0.2	Fine sand *KHt* 0.2—0.06	Very fine sand *HHt* 0.06—0.02
0—20	0.3	2.4	6.8	89.0	1.5
20—40	—	1.6	3.7	94.4	0.3
40—60	—	6.9	11.1	81.8	0.2
60—80	—	3.8	8.0	87.9	0.3
80—100	—	1.1	5.8	93.1	—

The depths at which the temperatures were recorded were 5, 10, 20, 50 and 100 cm on both sites. At the depths of 50 and 100 cm only one thermocouple each was placed, whereas two replicates were used at the other depths.

2. *Meteorological conditions*

Table 2 shows the conditions of temperature and rainfall. The normal temperature values have been calculated from the years 1901—1930. However, a consistent increase of the temperatures has taken place after 1930, so that the annual mean temperature has increased by 1—1.5°C (KERÄNEN 1952).

Table 2. Temperature and rainfall at the climatological station in Pelsonsuo.

Taul. 2. Lämpötila ja sademäärä Pelsonsuon ilmastoasemalla.

Month *Kuukausi*	Temperature, °C *Lämpötila °C*			Rainfall, mm *Sademäärä mm*			Number of rainy days *Sadepäivien lukumäärä*	
	Normal mean temp. *Normaali keski-lämpötila*	Deviation from normal *Poikk. normaalista*		Normal value *Normaali-arvo*	Deviation from normal *Poikkeama normaalista*			
		1955	1956		1955	1956	1955	1956
January	—10.3	—0.4	—2.4	40	+ 5	— 9	16	14
February	—11.0	—4.1	—6.2	32	— 8	— 3	15	12
March	— 6.8	—4.1	—1.4	30	— 7	— 15	15	7
April	— 0.3	—3.9	—3.3	34	— 8	— 26	9	6
May	5.9	—4.4	+2.2	42	—10	— 16	11	5
June	11.8	—0.8	+2.8	61	—30	+ 13	10	10
July	15.2	+0.5	—0.4	71	— 1	— 44	8	12
August	12.3	+3.1	—1.3	77	—65	— 3	5	23
September	7.2	+3.1	—1.2	62	+27	— 26	18	13
October	0.7	+0.1	—0.2	63	+ 2	— 17	—	16
November	— 4.3	—3.6	—5.6	47	+ 6	— 34	—	12
December	— 8.5	—8.9	+0.9	43	+ 5	— 17	—	10
Year *Vuosi*	1.0	—0.3	—1.3	602	—84	—194	—	152

Freezing of the ground in the wintertime occurs regularly in the region in question, the depth of the frozen ground layer varying between 20 and 40 cm in the bog. The number of months during which a snow cover is present usually varies between 4 and 6 (cf. PESSI 1956, p. 30).

Table 3 shows the total radiation values observed at Pelsonsuo during the summers concerned in this investigation.

Table 3. Total radiation at Pelsonsuo, cal/cm², in 1955—1956.
Taul. 3. Kokonaissäteily Pelsonsuolla vuosina 1955—1956, cal/cm²

Year / *Vuosi*	VI	VII	VIII	XI
1955	13 314	13 868	10 300	3 555
1956	12 883	12 804	9 150	

II. Equipment and methods

The *soil temperature measurements* were performed with the aid of measuring equipment which operates on the thermocouple principle, combined with a resistance thermometer for cold junction compensation. A detailed description of the equipment has been given earlier (Pessi 1956, p. 17—24).

The *radiation balance* was measured with the aid of a net radiation meter developed by Suomi, Franssila and Islitzer (Franssila 1953, Suomi et al. 1954). This instrument was compared in May 1954 with the Michelson bimetal actinometer. The net radiation meter was used in conjunction with the galvanometer belonging to the temperature measuring equipment (cf. Pessi 1956, p. 25). As it had been calibrated during the daytime, a correction was applied to the observations made during the night (Suomi 1954, p. 279—280).

The *total radiation* was measured with the aid of a Robitzsch bimetal pyranograph. This instrument was placed at a height of 1.5 m from the soil surface, about 200 m to the south of the temperature measurement point on the peat soil.

The *specific weight* of the soil was determined by means of Albert and Bogs' (1914) rapid method. The taking of the soil samples and the technical performance of the determination have been described in an earlier publication (Pessi 1956, p. 26—27).

The *moisture content* of the soil was determined by weighing, keeping the samples at 105°C overnight.

The *specific heat* of the soil is usually determined calorimetrically. Since no calorimeter proper suitable to this purpose was available, the possibility of calculating the specific heats theoretically was investigated and upon completion of the investigation this method was adopted. The heat capacities of the soil ingredients and of the water contained in the soil were calculated separately and their sum was expressed in terms of the specific heat of the soil sample. The specific heats of peat and mineral soil were taken as 0.48 and 0.22 cal/g °C respectively (Karsten 1917, p. 320).

The *depth of the ground water level* from the soil surface was followed throughout the investigation series by means of special measurements, for which purpose ground water pipes made of boards were placed in the middle

of the strip between the ditches, and at a distance of 1 m from the edge of the ditch. The depth of the water level in the pipes was measured with a graduated rod, ripples on the water surface indicating the moment when the rod touched the water.

Evaporation was assessed by observing, with the aid of weighings, the loss of weight of soil samples taken for this purpose, as follows: A cylinder, 16 cm in diameter and 10 cm in height, with a sharpened rim, was pushed into the soil. The soil sample was cut with a knife at the lower rim of the cylinder, and the cylinder was lifted off, together with the sample. The lower end of the cylinder was covered tightly with a rubber-gasketed plate. After weighing, the samples were placed in a hole made in the ground, so that the upper surface of the sample was level with the soil surface. Weighings were made at intervals of a few hours, the weighing accuracy being 0.1 g. New samples were taken for each day, and samples were also taken at intervals of a few hours during one and the same day. Three replicates were used in these observations.

The *density of the snow cover* was determined at a place adjacent to the point of measurement, using the snow balance designed by KORHONEN and MELANDER (KORHONEN 1922). Three replicate determinations were made.

The *depht of the snow cover* was recorded with the aid of graduated sticks stuck into the soil at each temperature measurement point.

III. The investigations and their results

1. Distance of the ground water level from the soil surface

The measurements of the ground water level are shown in Table 4. It is seen from the results that the ground water rose regularly every spring to the height of some of the points of measurement, remaining there for a certain time, and once in the autumn of 1955 it rose to the height of 100 cm below the soil surface.

Table 4. Depth of ground water level from the soil surface at the points of temperature measurement.

Taul. 4. Pohjaveden pinnan etäisyys maan pinnasta lämpötilanmittauspaikoilla.

Date *Päivä*	Depth, cm *Etäisyys cm*		Date *Päivä*	Depth, cm *Etäisyys cm*	
	Peat soil *Turve*	Mineral soil *Kiv. maa*		Peat soil *Turve*	Mineral soil *Kiv. maa*
16. V. 1955	25	—	3. V. 1956	25	31
23. V.	120	—	8. V.	40	49
31. V.	91	95	16. V.	65	71
7. VI.	110	113	24. V.	98	>113
15. VI.	135	>113	31. V.	103	95
20. VI.	156	—	9. VI.	80	82
24. VI.	>156	—	21. VI.	156	113
29. IX.	140	—			
6. X.	156	—			
16. XI.	87	100			
30. XI.	>156	>113			

2. Snow cover

Observations of the depth of the snow cover were made only infrequently during the winter 1955—1956, because the depth of the snow differed greatly between the different points of measurement, thus precluding any study of the influence of the soil type upon thermal conditions in the soil during the winter.

Throughout the winter the snow cover was less on the mineral soil than on the peat soil. The snow which remained throughout the winter fell in the latter half of November. On 12. XII. 1955 the depth of snow was 20 cm on the mineral soil and 13 cm on the peat soil, on 14. I. 1956 it was 32 cm and 25 cm respectively, on 14. II. 1956, 45 cm and 25 cm, on 19. III. 1956, 43 cm and 35 cm, and on 21. IV. 1956, 35 cm and 15 cm. The snow cover disappeared on 4. V. 1956.

During the winter the peat soil froze down to 41 cm. The depth to which the mineral soil froze could not be determined, since the iron rod provided for this purpose did not reach below a depth of 100 cm, and the ground froze deeper than this.

3. Insertion of the thermocouples, and their depths from the soil surface during the investigation

The considerations taken into account when placing the thermocouples in the soil and the procedure of their insertion have been described in detail earlier (Pessi 1956, p. 31—32).

In addition to the thermocouples at the depths mentioned in the foregoing, one thermocouple was kept on the soil surface during the winters. Whenever the temperature at soil surface was measured in the summer, the copper sheath of the thermocouple and about 5 cm of the adjoining leadwire were placed horizontally on the soil surface and covered by a soil layer of about 1 mm (cf. Wild 1879, Leyst 1890). In such cases two replicates were employed.

Towards the end of the observation period an investigation was made concerning the actual depths at which the thermocouples were located. In the mineral soil no settling of the soil had occurred, and the thermocouples were indeed found to lie at exactly their original depths. On the other hand, settling had taken place in the peat soil. The depths of the thermocouples were estimated on the basis of the initial and ultimate depths, and the observed temperatures have been corrected to correspond to depths of exactly 5, 10, 20, 50 and 100 cm below soil surface (cf. Pessi 1957).

4. Soil temperatures

a. Computation of mean temperatures

The daily times of observation in the summertime (May to September) were at 8.00 and 20.00 hours. On certain days observations were also made every hour throughout the 24 hours. In the winter months the temperatures were measured only once a day, at 14.00 hours.

It has been mentioned in the foregoing that at the depths of 20 cm and less two replicates were used for each depth. In the mineral soil the readings of these replicates differed very little, the variation being not more than 0.5°C. In the peat soil the differences between the replicates were greater: they were of the same order of magnitude as in an earlier investigation (Pessi 1956, p. 35).

On account of the distance of 2 km between the sites of measurement, the following procedure was observed in the summer: The temperatures in the peat soil were measured first, then those in the mineral soil, and once more the temperatures in the peat soil. The commuting from one site to another took about 20 minutes. The means of the double determinations in the case of the peat soil were taken as representing the peat soil temperatures corresponding to the single observations from the mineral soil. However, one single determination for the peat soil was often considered sufficient on cloudy days with fairly even air temperature. The daily mean temperatures were computed in the same manner as in an earlier investigation (Pessi 1957).

Soil temperature observations could not be made every day. In the summer months the intervals between the days of observation were of a few days' length (v. Table 5), whereas during the winter observations were made about once a month. The monthly mean temperatures have been computed as follows.

At the depths of 50 and 100 cm the temperatures vary at such a slow rate that the temperatures of the intermediate days can be interpolated with adequate accuracy from the daily mean temperatures spaced at intervals of a few days. This was done, and the monthly means were then computed from the mean temperatures of every day. The monthly mean temperature values obtained for these two depths can be considered highly representative. The annual extremes and their times of occurrence can also be exactly determined for these depths.

At the depths of 5, 10 and 20 cm, on the other hand, the daily mean temperatures do not vary as regularly as at 50 and 100 cm, which is due to the daily variation of the meteorological elements. For this reason no great accuracy can be expected if the mean temperatures of the intermediate days are determined by interpolation. The computation of the monthly mean temperatures for the said depths was performed in the following manner.

The course of the temperature was smoothed on the basis of the mean temperatures of the days of observation to give a regular curve such as could be assumed would appear in absence of daily disturbances from the meteorological elements. The curves were, moreover, drawn in such a way that, by visual assessment, the deviations of the mean temperatures of the days of

observation from the curve would satisfy the principle of the least squares. From the curves obtained in this way the mean temperature of each day was read, and the monthly mean was computed from these values.

In consequence of this procedure it is not possible to determine accurately the annual extremes and their times of occurrence, but on the basis of the

Table 5. Daily mean soil temperatures of the days
Taul. 5. Havaintovuorokausien keski-

Depth, cm *Syvyys cm*		June 1955 *Kesäkuu 1955*							July 1955 *Heinäkuu 1955*					
		1.	7.	11.	15.	20.	24.	28.	2.	8.	13.	20.	26.	29.
Peat soil *Turve*	Soil surface *Maanpinta*													
	5	4.6	5.3	3.5	10.0	7.6	12.0	10.2	14.5	14.7	18.9	14.0	16.2	16.9
	10	3.5	4.6	4.4	7.7	5.4	10.6	8.9	12.6	15.4	18.2	13.0	15.6	16.7
	20	1.1	1.1	1.2	2.4	2.3	8.8	7.8	11.0	12.0	14.5	11.8	13.4	14.8
	50	0.4	0.5	0.6	0.6	1.1	2.8	4.6	6.5	7.3	9.0	9.6	9.7	10.3
	100	1.4	1.4	1.4	1.4	1.7	1.8	2.1	2.4	3.6	4.9	5.7	6.8	7.2
Mineral soil *Kivmaa*	Soil surface *Maanpinta*													
	5	10.0	8.6	9.5	13.7	10.8	15.4	13.4	17.8	18.2	21.9	14.5	16.6	19.5
	10	7.9	8.7	6.8	12.3	9.9	14.8	13.1	16.8	17.6	20.8	13.7	15.6	18.7
	20	7.4	8.7	5.4	10.4	8.7	13.0	12.2	15.2	16.2	19.1	12.4	13.7	17.7
	50	4.8	7.6	5.7	7.6	7.6	9.6	10.0	11.7	13.6	15.1	11.9	13.1	14.9
	100	2.4	5.4	5.0	6.0	6.3	7.4	7.7	8.9	10.4	11.2	11.2	11.4	12.0

Depth, cm *Syvyys cm*		Dec. 1955 *Joulukuu 1955*	Feb. 1956 *Helmikuu 1956*	March 1956 *Maaliskuu 1956*	Apr. 1956 *Huhtikuu 1956*	May 1956 *Toukokuu 1956*					June 1956 *Kesäkuu 1956*		
		12.	14.	10.	21.	3.	8.	16.	24.	31.	9.	15.	21.
Peat soil *Turve*	Soil surface *Maanpinta*	3.4	4.8	1.5	—0.5	0.1							
	5	—3.0	—4.6	—1.3	—0.5	0.0	7.4	6.8	10.2	6.0	16.0	16.2	15.1
	10	—2.1	—3.2	—1.2	—0.5	0.0	0.2	1.3	3.7	2.7	12.0	12.2	11.8
	20	—1.3	—2.1	—1.1	—0.5	0.0	0.2	0.2	1.4	1.9	6.3	6.2	6.3
	50	1.4	0.6	0.0	0.0	0.1	0.2	0.2	0.2	0.6	0.7	0.6	0.6
	100	3.0	1.9	1.5	1.2	1.1	1.1	1.2	1.2	1.5	1.7	1.6	1.6
Mineral soil *Kivmaa*	Soil surface *Maanpinta*	—8.0	—9.6	—2.5	—								
	5	7.0	9.7	2.4			9.7	8.5	11.2	5.0	16.5	16.4	15.9
	10	—6.4	—9.2	—2.2	—	—	8.6	6.0	8.5	3.8	15.2	15.3	15.0
	20	—4.9	—8.2	—2.0	—	—	5.2	4.2	6.5	3.8	13.2	13.2	12.8
	50	—0.3	—4.0	—1.0	—	—	0.2	0.2	2.6	3.3	7.7	8.4	9.1
	100	1.7	0.0	0.0	—	—	0.2	0.2	0.2	0.6	4.5	5.6	6.5

available observation material there is hardly any alternative way to accomplish this. The monthly mean temperatures are not fully representative either, but their accuracy should be well sufficient for practical purposes.

The monthly means relating to the soil surface were determined by extrapolation from the temperatures at the other depths.

of observation at different depths, 1955—1956.
lämpötilat eri syvyyksissä 1955—1956.

August 1955 *Elokuu 1955*				September 1955 *Syyskuu 1955*					Oct. 1955 *Lokakuu 1955*			Nov. 1955 *Marraskuu 1955*		
8.	15.	22.	26.	1.	8.	15.	22.	29.	6.	11.	19.	8.	16.	30.
													−0.2	−2.8
18.3	15.5	17.0	15.8	13.6	12.8	10.4	9.8	7.0	1.1	8.0	0.3	−0.3	0.5	−2.8
16.0	15.3	16.3	15.4	12.3	10.3	10.1	10.0	7.1	2.6	6.1	0.6	−0.3	0.5	−2.2
14.0	14.3	15.0	13.9	12.4	10.8	10.1	10.0	8.2	5.2	6.1	2.4	−0.1	1.3	−0.4
10.8	10.8	11.4	11.4	10.8	10.5	10.1	10.0	9.3	7.5	7.0	5.0	3.0	3.0	2.0
7.9	7.8	8.3	8.5	8.9	8.7	8.6	8.6	8.6	7.7	7.4	5.9	4.6	4.6	3.4
													−0.1	−2.4
17.8	18.0	18.5	17.2	14.0	11.8	10.6	9.5	7.0	0.7	6.9	−0.4	−0.2	0.1	−2.4
16.7	18.1	18.9	16.7	12.8	10.4	10.4	9.5	6.8	1.4	5.8	0.2	−0.1	0.2	2.1
15.5	17.0	18.0	13.7	12.8	9.9	10.2	9.6	7.0	2.6	4.9	1.3	0.5	0.8	−1.0
13.4	14.6	15.6	13.9	12.5	11.0	10.4	10.4	8.0	5.2	5.9	3.7	2.0	2.0	1.0
11.4	12.1	12.9	12.0	11.4	10.9	10.5	10.5	8.8	7.2	6.7	5.9	3.6	3.1	2.3

July 1956 *Heinäkuu 1956*				August 1956 *Elokuu 1956*				September 1956 *Syyskuu 1956*			
7.	13.	21.	30.	7.	15.	21.	28.	4.	12.	19.	25.
15.9	14.7	14.0	15.1	14.8	11.4	11.0	10.5	7.9	7.7	5.5	7.2
12.6	14.2	12.6	12.6	13.8	11.2	10.9	10.4	7.8	7.7	6.0	6.6
10.2	11.2	10.8	10.0	12.5	10.8	10.5	10.3	7.9	7.7	6.6	6.1
4.0	6.0	7.9	7.2	10.2	9.4	9.4	9.4	9.1	7.6	7.0	6.8
1.7	2.7	4.7	4.8	7.2	8.1	8.2	8.1	7.6	7.4	6.8	6.8
20.1	23.7	18.2	18.5	14.5	13.7	12.6	10.7	7.2	7.4	5.0	9.5
19.5	20.4	16.7	17.8	14.1	13.3	12.2	10.5	7.1	7.4	5.1	8.4
17.1	19.1	12.5	13.0	13.4	12.6	11.6	10.5	7.1	7.4	5.4	7.0
13.2	12.7	11.6	11.3	11.8	11.2	10.4	10.2	7.8	7.2	6.7	5.9
9.1	9.4	9.6	9.2	9.6	9.7	9.3	9.2	8.3	7.1	6.9	6.3

b. Mean temperatures

The mean temperatures of the days of observation are seen from Table 5. The monthly mean temperatures have been given in Table 6 as well as in Fig. 2 and 3.

It is seen from the figures that similar differences have developed between the temperatures of the two soil types in both summers. The greatest differences in monthly mean temperature occur in June, but differences of several °C are still observed in July and August. In September the temperature differences are already fairly small. Comparison of the temperature differences between the soil types at different depths shows that the surface temperatures are nearly equal on both soils in the summer months, a circumstance which was also observed in the temperature measurements in connection with experiments concerning the use of soil improving agents (Pessi 1956, p. 51).

Since the snow cover was different on the different soil types, this fact has obviously affected the temperature differences during the time December-April, and the soil type is not exclusively responsible for them.

c. Annual variation of temperatures

The annual variation of the soil temperatures is shown in Fig. 4. On comparison of the course of the isotherms in the two soil types the different snow covers during the winter have again to be taken into account.

Table 6. Monthly mean soil temperatures, 1955—1956.
Taul. 6. Kuukauden keskilämpötiloja vuosilta 1955—1956.

Depth, cm. *Syvyys cm*	1955							1956								
	VI	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX
Air *Ilma 2m*	11.0	15.7	15.4	10.3	0.8	—7.9	—17.4	—12.7	—17.2	—8.2	—3.6	8.1	14.6	14.8	11.0	6.0
Soil surface *Maanpinta*	11.0	18.5	17.5	5.4	0.0	—1.0	— 4.5	— 5.3	— 5.5	—2.6	—0.5	10.5	18.0	19.0	15.0	8.0
5	8.1	16.7	16.6	7.4	1.1	—0.6	— 3.3	— 4.4	— 4.4	—2.1	—0.7	6.5	14.9	16.0	12.2	7.5
10	5.9	14.8	15.8	9.2	2.4	—0.2	— 2.2	— 3.6	— 3.0	—1.4	—0.8	1.6	9.8	13.2	11.4	7.0
20	3.8	12.6	14.2	10.3	4.0	1.0	— 1.4	— 2.4	— 1.8	—1.4	—0.8	0.2	5.9	11.0	11.1	7.2
50	2.2	8.5	10.6	9.9	6.1	2.9	1.4	0.9	0.6	0.1	0.0	0.1	0.9	5.6	9.7	7.7
100	1.7	4.8	7.9	8.6	6.8	4.3	2.9	2.3	1.9	1.5	1.2	1.1	1.6	3.2	7.3	7.2

Peat soil — *Turvemaa*

Depth, cm. *Syvyys cm*	1955							1956								
	VI	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX
Soil surface *Maanpinta*	13.5	18.6	17.3	10.4	2.4	—1.8	— 6.3	— 9.3	— 9.8	—3.7	0.2	10.2	17.5	20.2	14.8	7.8
5	12.0	18.2	17.4	10.2	2.4	—1.5	— 6.2	— 9.3	— 9.2	—3.6	0.2	7.5	15.3	19.4	13.8	7.8
10	10.8	17.9	17.6	9.8	2.4	—0.8	— 6.0	— 9.2	— 8.6	—3.5	0.2	5.8	14.0	18.5	12.9	7.8
20	9.7	16.6	16.4	9.4	2.7	—0.6	— 4.8	— 7.0	— 7.5	—3.4	—0.4	3.8	11.4	16.6	12.6	7.2
50	7.6	13.1	14.2	10.4	4.3	1.9	— 0.4	— 2.6	— 3.5	—1.4	—0.1	1.1	8.4	12.1	10.8	7.3
100	6.0	10.5	12.0	10.3	6.2	3.1	1.5	0.6	0.0	0.0	0.0	0.2	5.2	9.1	9.4	7.3

Mineral soil — *Kivennäismaa*

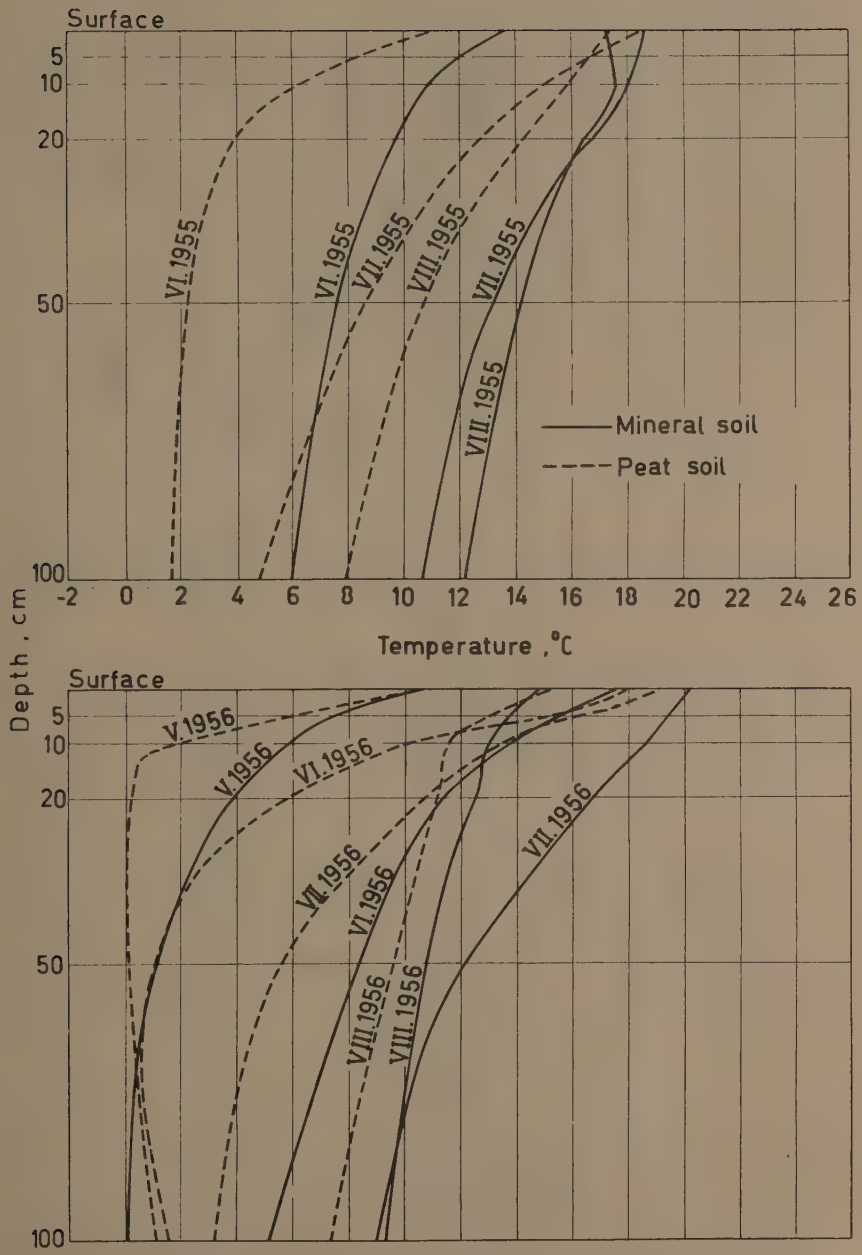

Fig. 2. The monthly mean temperature profiles in 1955—1956.
Kuva 2. Kuukauden keskilämpötilaprofiileja 1955—1956.

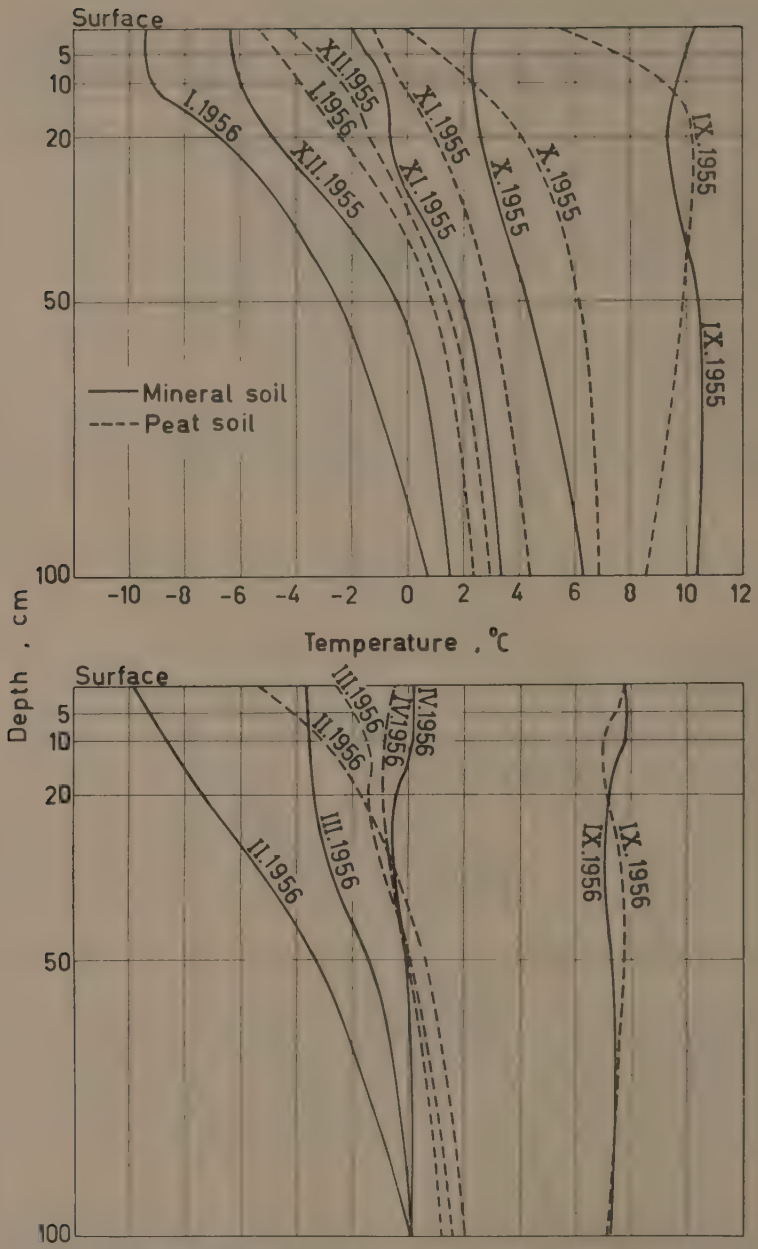

Fig. 3. The monthly mean temperature profiles in 1955—1956.
Kuva 3. Kuukauden keskilämpötilaprofiileja 1955—1956.

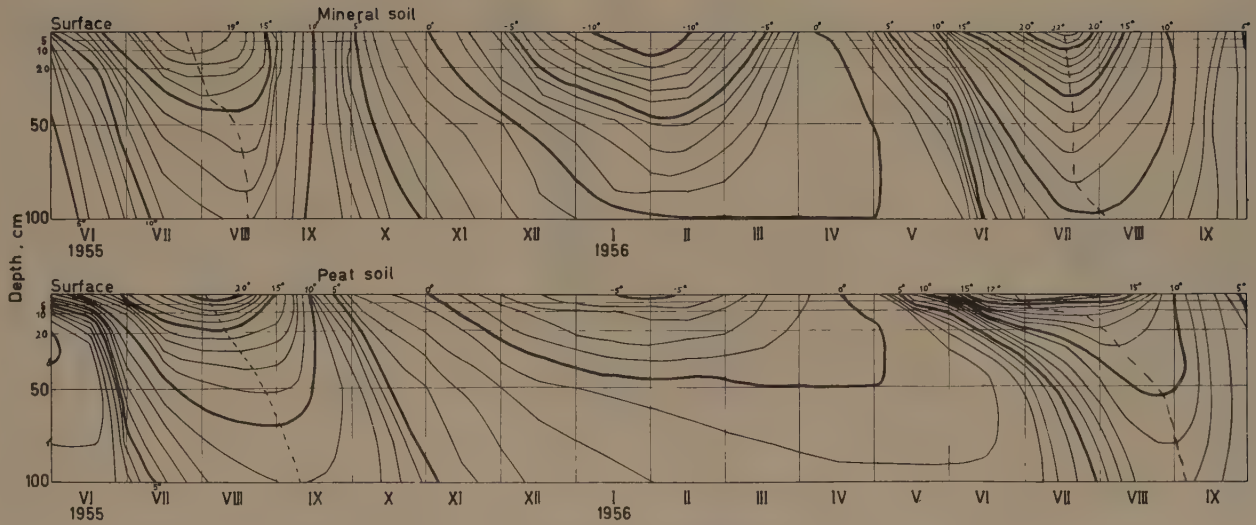

Fig. 4. Variation of the temperature in the mineral and peat soils during the period 1. VI. 1955—30. IX. 1956.
Kuva 4. Lämpötilan kulku kivennäis- ja turvemaassa 1. VI. 1955—30. IX. 1956.

The isotherms show that inversion of temperature takes place in both soil types at the same time in the autumn, about the middle of September. This same period has been established as the time of inversion in several other investigations (Keränen 1920, Harrington 1928, p. 192, Semb 1939, p. 9).

On comparison of the course of the isotherms, temperature differences conforming in direction with those occurring in the monthly mean temperature profile are observed. The freezing of the soil in the autumn is found to start earlier in the mineral soil than in the peat soil. This is particularly clearly evident in the autumn of 1956.

d. Daily variation of temperatures

The daily variation of the soil temperatures was studied by means of a few observation series consisting of temperature measurements made once every hour throughout the 24 hours. Fig. 5 and 6 show tautochrones from two days. The manner in which the daily variation of temperature manifests itself in the different types of soil can be clearly seen from these tautochrones. Differences similar in type are also seen in the temperature variations in Homen's (1897) investigations (cf. Pessi 1956, p. 65).

5. Thermal conductivity

It is well-known that mineral soil and peat soil differ in regard to their thermal conductivity. This fact is partly responsible for the difference in thermal conditions between the two soils. According to several investigators, the thermal conductivity values for peat soil in the completely dry state and when saturated with water are about 0.00027 and 0.0011 cal/cm s °C, respectively; the corresponding values, e. g., for sand being 0.00047 and 0.0041 (Homen 1896, Karsten 1911, p. 32, Smith 1938, p. 17, 1939, p. 33, DeVries and DeWitt 1954, p. 42).

The thermal conductivities of the soils have been computed in a manner described in detail previously (Pessi 1956, p. 75). In this way, the mineral soil was found to have a thermal conductivity of 0.0023 cal/cm s °C in the 5 to 20 cm layer at a moisture content equal to 45 % of saturation. The thermal conductivity for the corresponding layer of the peat soil at 58 % of saturation was calculated as 0.0008 cal/cm s °C. However, the thermal conductivity of soil is dependent on its moisture content and, according to Karsten (1911, p. 36), the effect of moisture is stronger in mineral soils than in peat soils.

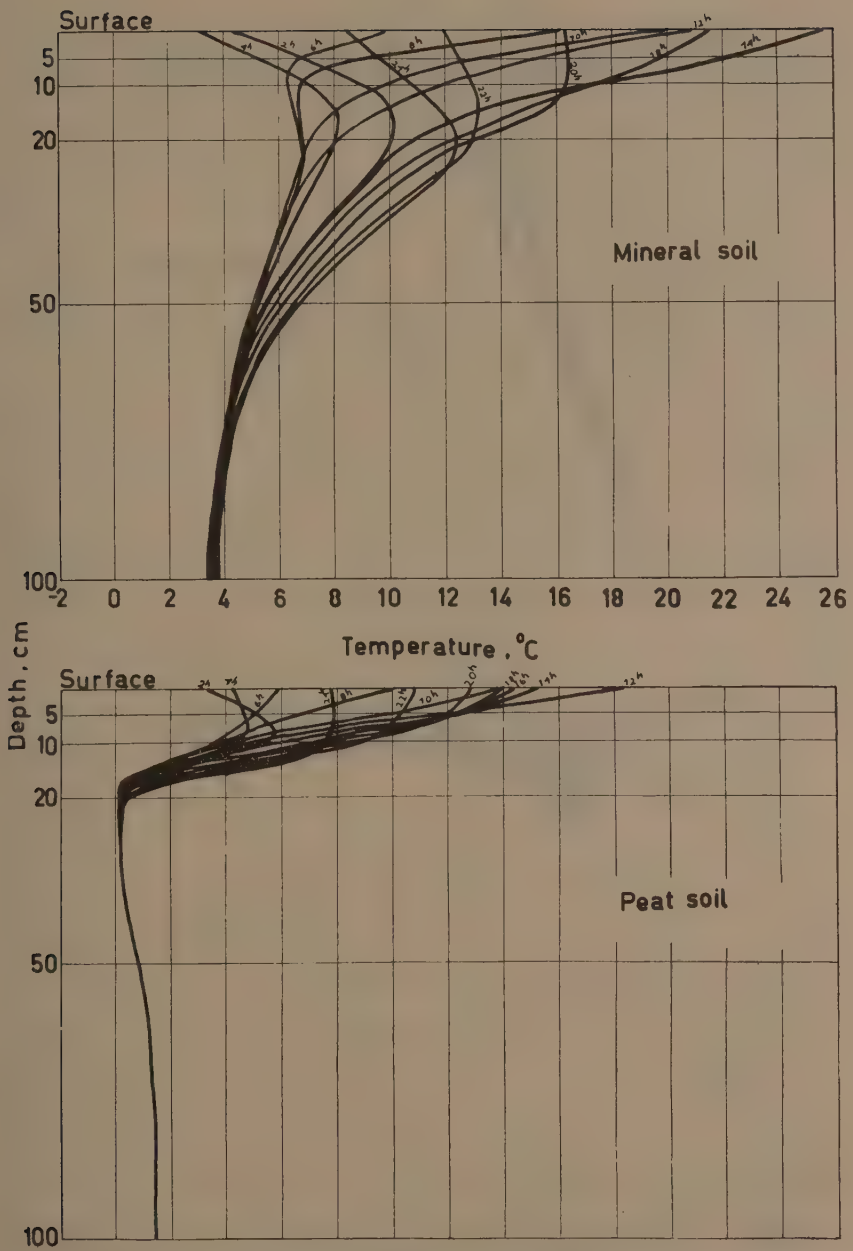

Fig. 5. Temperature of the mineral and peat soils at certain hours on 1. VI. 1955.
Kuva 5. Kivennäismaan ja turvemaan lämpötila tiettyinä tunteina 1. VI. 1955.

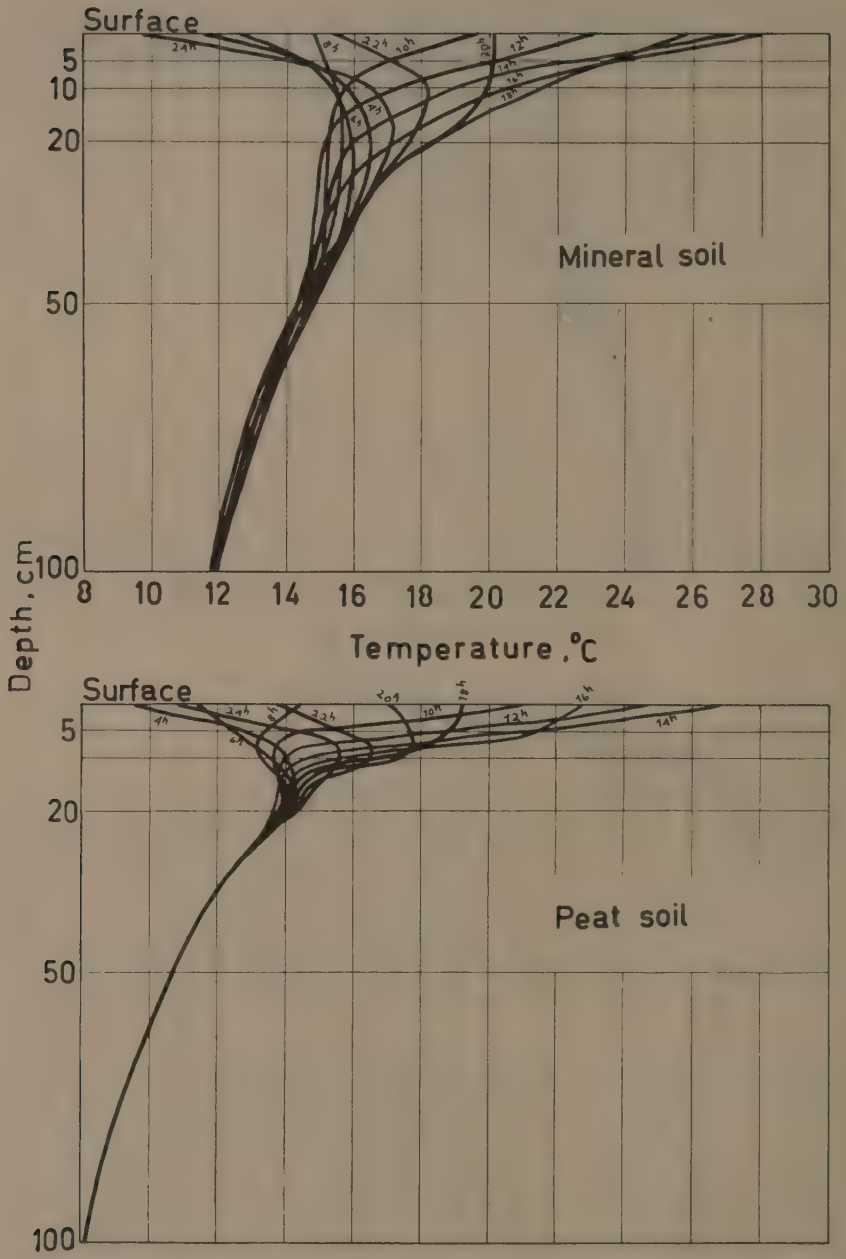

Fig. 6. Temperature of the mineral and peat soils at certain hours on 15. VIII. 1955.
Kuva 6. Kivennäismaan ja turvemaan lämpötila tiettyinä tunteina 15. VIII. 1955.

6. Radiation balance

The mineral soil was lighter in colour than the peat soil. As the colour is of considerable significance in regard to the absorption of thermal radiation, it can already be expected for this reason that the radiation balance will be considerably different for the two types of soil. According to Bouyoucos (1913, p. 30—33), the colour of the soil has only little or no influence upon emission of thermal radiation, but exerts considerable influence upon its absorption.

Although a radiation meter was available in the present investigation, simultaneous measurements could not be made on account of the great distance between the test areas. Instead of this, the net radiation balances of two test plots of an experiment relating to the use of soil improving agents (cf. Pessi 1956, p. 74) are shown in Fig. 7, which may serve to illustrate this question. In one of the plots 800 m^3 of sand per hectare had been admixed to the peat, whereas no addition had been made to the other plot. The addition of mineral soil has rendered the soil considerably lighter in colour. It is seen from the radiation balance curves that the colour of the soil has had a distinct effect.

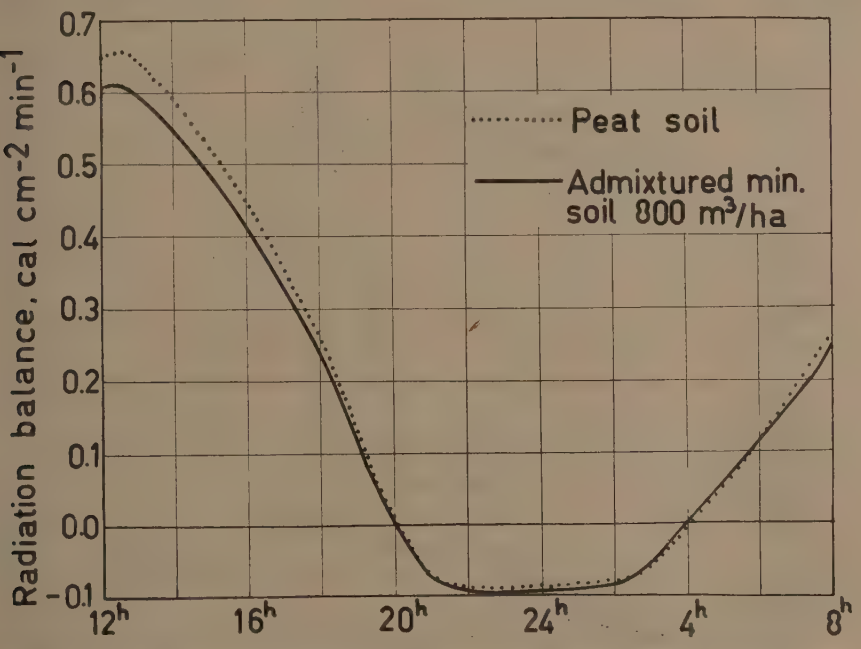

Fig. 7. Radiation balance of peat soil and of soil to which mineral soil (800 m^3/ha) has been admixed. Date: 27—28. V. 1954.

Kuva 7. Maan pinnan säteilytase 27—28. V. 1954 turvemaassa ja maassa, johon on sekoitettu kivennäismaata (800 m^3/ha).

7. *Evaporation*

Part of the radiant energy arriving on the soil surface is consumed to sustain the evaporation of water. It is a generally acknowledged opinion that more water evaporates from peat soil than from mineral soil. For this reason, for instance, the admixture of mineral soil to peat reduces the evaporation (Seyfert 1891, p. 854, Tacke and Densch 1916, Krüger 1922).

Homen (1897) has investigated the evaporation from sand and from peat one day in each of the months of August, September and October. The water quantity which evaporated from sand in August consumed 16 % of the sun's radiation, that from peat 48 %. The corresponding figures for September and October were 28 and 43 %, and 15 and 20 %, respectively.

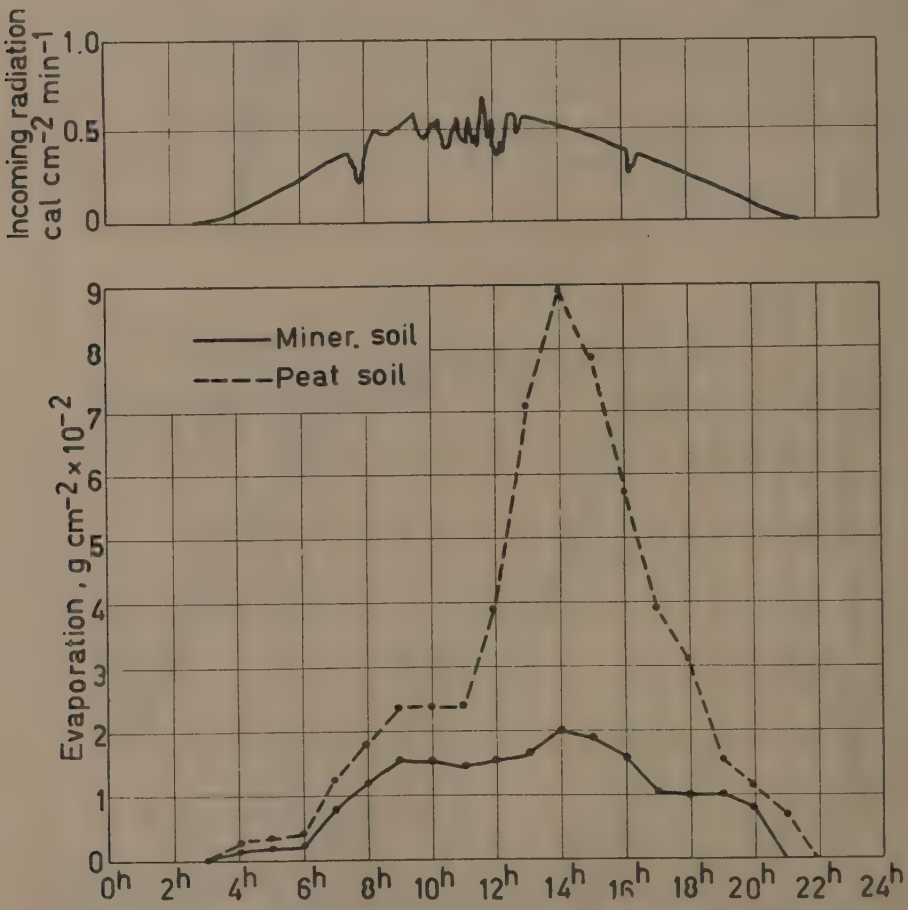

Fig. 8. Incoming radiation and evaporation from the mineral and peat soils on 1. VI. 1955.
Kuva 8. Tulosäteily ja haihtuminen kivennäis- ja turvemaasta 1. VI. 1955.

Fig. 8 shows the evaporation which took place from mineral soil and from peat at Pelsonsuo on 1. VI. 1955. The evaporation from peat was considerably higher than that from mineral soil, the loss of water per 24 hours being 0.56 and 0.20 g/cm^2, respectively. However, the conditions of moisture content were not identical. A peat layer of 10 cm thickness contained water to an amount of 54.9 % of the total porous space, the corresponding figure for the mineral soil being 17.4 %. The day of observation was preceded by six rainless days, during which this moisture condition of the soils had been established.

Summary

In the present work the thermal conditions in mineral soil and in peat soil between the depths of 0 and 100 cm below soil surface are described. The investigation has been carried out at Pelsonsuo ($\lambda = 26.5°$ E, $\varphi = 64.3°$ N) in the years 1955—1956. The peat soil consisted of sedge peat, and the mineral soil of coarse sand. Some of the causes which give rise to differences in soil temperature are enumerated.

The most essential results of this investigation are:

1. In May, June, July and August the mean temperatures in the mineral soil are higher than those in the peat soil. The greatest temperature differences between the two soil types occur in June. In September the mean temperatures are nearly equal. In all other months lower temperatures prevail in the mineral soil.

2. In the summer months the differences between the two soil types with regard to monthly mean temperatures are such that the soil surface temperatures are nearly equal, the differences increasing with greater depth. In May and June, however, the greatest temperature differences occurred in the layers of 10 to 50 cm depth.

3. The daily temperature variations extend down to a depth of 70—80 cm in the mineral soil on cloudless days, and to a depth of 25—30 cm in the peat soil.

4. The thermal conductivity of mineral soil is considerably higher than that of peat soil.

5. Peat soil absorbs more thermal radiation than mineral soil. This is partly due to the different radiation balance which develops during the daytime. During the night the radiation balance is nearly equal in both soils.

6. Considerably more water evaporates from peat soil than from mineral soil.

7. A considerable indirect effect upon the thermal conditions in the soil results from the fact that frozen mineral soil thaws earlier than peat soil.

Acknowledgement

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Selostus

Kivennäismaan ja turvemaan lämpöoloista Pelsonsuolla vuosina 1955—1956

Yrjö Pessi

Maatalouden tutkimuskeskus,
Hallakoeasema, Pelsonsuo

Esillä olevassa työssä selostetaan kivennäismaan ja turvemaan lämpöoloja 0—100 cm:n kerroksessa. Tutkimukset on suoritettu vuosina 1955—1956 Pelsonsuolla (λ = 26.5° E. φ = 64.3° N). Turve oli saraturvetta ja kivennäismaa karkeata hietaa. Lisäksi selostetaan eräitä tekijöitä, joista maan lämpöoloissa esiintyvät eroavuudet johtuvat. Tärkeimmät tutkimustulokset ovat seuraavat:

1. Touko-, kesä-, heinä- ja elokuun kuukauden keskilämpötilat ovat kivennäismaassa korkeampia kuin turvemaassa. Suurimmat maalajien keskeiset lämpötilaerot esiintyvät kesäkuussa. Syyskuun keskilämpötilat ovat lähes samanlaisia, mutta muulloin kivennäismaan lämpötilat ovat alhaisempia.

2. Maalajien keskeiset kuukauden keskilämpötilaerot ovat kesäkuukausina olleet sellaisia, että pintalämpötilat ovat lähes samanlaisia, mutta alaspäin mentäessä lämpötilaerot suurenevat. Touko-kesäkuussa suurimmat lämpötilaerot esiintyvät kuitenkin 10—50 cm:n kerroksessa.

3. Vuorokauden lämpötilanvaihtelut ulottuvat kivennäismaassa selkeinä vuorokausina noin 70—80 cm:n syvyydelle, turvemaassa noin 25—30 cm:n syvyydelle.

4. Kivennäismaan lämmönjohtavuus on huomattavasti suurempi kuin turvemaan.

5. Turvemaa absorboi enemmän lämpösäteilyä kuin kivennäismaa, mistä osaltaan johtuu päivisin eri maalajeilla esiintyvien säteilybilanssien erilaisuus. Yöllä säteilybilanssi on lähes samanlainen.

6. Turvemaasta haihtuu vettä huomattavasti enemmän kuin kivennäismaasta.

7. Huomattava välillinen vaikutus maan lämpöolojen muodostumisessa on sillä, että routa sulaa nopeammin kivennäismaasta kuin turpeesta.